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ABSTRACT: Calculations have been made of the flow field in the isentropic region behind a detonation wave in TNT, using the Landau-Stanyukovich equation of state for the detonation products (as described by Zeldovich and Kompaneets). Adjustable constants in this equation have been evaluated by imposing ideal gas behavior on the detonation products in the large expansion (low density) limit, and by fitting to an experimental curve of detonation velocity versus loading density. Calculated values of Chapman-Jouguet variables correspond fairly well with experimental values at various loading densities, with the exception of the temperatures, which seem to be far too low. This is connected with the fact that the theory predicts an upper limit to the loading density at which an explosive will detonate; at this point the thermal energy vanishes and only the elastic energy contributes to the energy of detonation.

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Calculations of the airshock motion produced by a spherical TNT explosion, with the reaction products considered to be gaseous, have given satisfactory agreement with experimental results However, the experimental motion of the explosive interface and the second shock have not agreed with the theoretical calculations. An attempt to clarify these discrepancies has led to consideration of the Landau-Stanyukovich solid state model for the reaction products of a condensed explosive. The Landau-Stanyukovich equation of state has been utilized to calculate the flow field in the reaction products behind the Chapman-Jouguet zone - the so-called Taylor Wave distribution - and the results are presented in this report Preliminary determinations of this distribution have already been used as initial conditions for the calculation of the subsequent explosion motion, and have been reported elsewhere.

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By direction

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INTRODUCTION

The theory of the detonation process for a γ-law gas, whose detonation product is also a γ-law gas, has been quite completely worked out and is available in many places.[1,2] In particular, the conditions at the Chapman-Jouguet state can be derived, and it can be shown that the detonation velocity is a function only of the heat of detonation and the γ for the detonation products, for sufficiently large detonation pressures. In addition, differential equations have been derived for the flow behind the detonation wave, and have been solved for certain explosives and geometries.[2,3,4]

The theory of the detonation of a solid explosive, on the other hand, is in a much less satisfactory state. Experiments[5,6] have shown that the detonation velocity of a solid explosive depends on the initial density, unlike the detonation velocity of gaseous detonations. Furthermore, the explosion products of condensed explosives are obtained at pressures of the order of megabars, and at densities approaching 2 grams/cm^3, under which conditions their behavior becomes extremely complex. Consequently, various attempts have been made to find an equation of state for the explosion products by treating the highly compressed gas as a solid.

The first such attempt is due to H. Jones,[7] who developed an equation of the Grüneisen type, based on the Einstein model of a solid, of the form $p = Ae^{-av}-B+fRT$, where a, A, B and f are constants. The equation of state which we consider in this paper, however, was derived by Landau and Stanyukovich,[8,9] who also approached the problem by drawing an analogy between the state of the detonation products of a condensed explosive and the crystal lattice of the solid state. It is well known that the energy of a solid body has a two-fold origin: it is made up of an elastic energy arising from the binding forces between the atoms and molecules and a thermal energy connected with oscillations of the atoms or molecules about their positions of stable equilibrium. Landau and Stanyukovich have attempted to describe the behavior of the detonation product by considering it as a solid with the property that the elastic energy and the elastic part of the pressure are predominant. The theory has been described and expanded by Zeldovitch and Kompaneets[8], so that we refer to it as the LSZK theory. The purpose of this paper is to make some computations using the LSZK equations of state, and, in particular, to calculate the flow field behind the detonation shock in a condensed explosive.

THE LSZK EQUATION OF STATE

For the sake of completeness, we present here a description of the LSZK equation of state, and a derivation of some of its properties.

The LSZK equation of state may be written[8]

$$P = \frac{B}{v^{\gamma}} + \frac{C_{v_1}\left(\frac{\gamma}{2} - \frac{1}{6}\right)}{v} T \qquad (1)$$

$$E = \frac{B}{(\gamma-1)v^{\gamma-1}} + C_v T , \qquad (2)$$

where P = pressure
E = energy density (per unit mass)
v = specific volume
T = temperature

and B, C_{v_1}, C_v and γ are constants. γ is a dimensionless constant serving as a polytropic index connected with the intermolecular forces; C_v is the specific heat at constant volume; C_{v_1} is a specific heat associated with the appropriate lattice vibrations; and B is a constant having the units $\left(\frac{gm}{cm^3}\right)^{1-\gamma} \frac{\text{calories}}{\text{gram}}$. The elastic part of the pressure is $\frac{B}{v^{\gamma}}$, and $\frac{B}{(\gamma-1)v^{\gamma-1}}$ is the elastic part of the energy.

Eliminating T between (1) and (2), we obtain the expression

$$P = \frac{E}{\alpha v} + \frac{B}{v^{\gamma}}\left\{1 - \frac{1}{\alpha(\gamma-1)}\right\} , \qquad (3)$$

where

$$\alpha = \frac{C_v}{C_{v_1}}\left\{\frac{1}{\frac{\gamma}{2} - \frac{1}{6}}\right\} . \qquad (4)$$

α is a convenient variable which will be used in this report. In terms of α, (1) and (2) may be written:

$$P = \frac{B}{v^{\gamma}} + \frac{C_v T}{\alpha v} \qquad (5)$$

$$E = \frac{B}{(\gamma-1)v^{\gamma-1}} + C_v T \tag{6}$$

Another convenient parameter which we will find useful is the quantity y, defined as the ratio of the thermal part of the pressure to the elastic part:

$$y = \frac{(C_v T/\alpha v)}{(B/v^{\gamma})} = \frac{C_v T}{\alpha B} v^{\gamma-1} \tag{7}$$

Clearly, (5) and (6) may now be written in the form:

$$P = \frac{B}{v^{\gamma}} (1 + y) \tag{8}$$

$$E = \frac{B\alpha}{v^{\gamma-1}} \left\{ y + \frac{1}{\alpha(\gamma-1)} \right\} \tag{9}$$

ISENTROPIC PROCESSES

It is possible to obtain an expression for the pressure of the form $P = P(\rho)$, valid for isentropic processes of an LSZK substance, by combining equation (3) with

$$dE = \frac{P}{\rho^2}\, d\rho \, , \tag{10}$$

which is the differential equation of an isentropic process. Differentiating (3), we obtain

$$dP = \frac{1}{\alpha}\,(\rho dE + E d\rho) + B\gamma\rho^{\gamma-1} \left\{1 - \frac{1}{\alpha(\gamma-1)}\right\} d\rho \tag{11}$$

Using (10) to eliminate dE from (11), we obtain

$$dP = \frac{1}{\alpha}\,(\frac{P}{\rho} d\rho + E d\rho) + B\gamma\rho^{\gamma-1} \left\{1 - \frac{1}{\alpha(\gamma-1)}\right\} d\rho \tag{12}$$

Solving (3) for E and substituting into (12), we obtain the differential equation

$$\frac{dP}{d\rho} - (\frac{1+\alpha}{\alpha})\,\frac{P}{\rho} = B\rho^{\gamma-1}\,(\gamma - 1 - \frac{1}{\alpha}) \tag{13}$$

which has the solution:

$$P(\rho) = K\rho^{\frac{1+\alpha}{\alpha}} + B\rho^{\gamma} \tag{14}$$

where K is a constant of integration. We are now in a position to obtain expressions for E, the sound speed c, the temperature T, etc. as functions of density alone, valid for isentropic processes of an LSZK substance. Thus, putting (14) into (3), and solving for E, we obtain:

$$E(\rho) = \alpha K\rho^{\frac{1}{\alpha}} + \frac{1}{(\gamma - 1)}\, B\rho^{\gamma-1} \tag{15}$$

Similarly,

$$T = \frac{\gamma K \rho^{\frac{1}{\gamma}}}{C_v} \tag{16}$$

and

$$c^2 = K\left(\frac{1+\alpha}{\alpha}\right)\rho^{\frac{1}{\alpha}} + B\gamma\rho^{\gamma-1} \tag{17}$$

CHAPMAN-JOUGUET CONDITIONS

We now obtain the initial conditions at an LSZK detonation, in terms of the variable y. We consider that the detonation wave consists of a shock traveling at speed D, followed immediately by a region of isentropic expansion. The region of chemical reaction behind the shock is considered to be infinitely thin. Values of the hydrodynamic parameters in the undetonated explosive ahead of the shock are given a subscript o so that v_o is the specific volume of the original explosive. We first obtain $\frac{v}{v_o}$ as a function of y. From the Rankine-Hugoniot (R-H) relations at the shock, we have

$$\frac{v_o}{v} = \frac{D}{D-u} \quad ; \tag{18}$$

where u = particle velocity
D = detonation velocity.

Using the detonation property $D = u + c$ (19)

equation (18) becomes

$$\frac{v_o}{v} = \frac{u}{c} + 1. \tag{20}$$

Another R-H relation yields

$$P = Du/v_o \tag{21}$$

which may be written in the form

$$\left(\frac{u}{c} + 1\right) \frac{u}{c} = \frac{Pv_o}{c^2} . \tag{22}$$

Using $P = B\rho^\gamma (1 + y)$ and the equation (20), (22) may be put into the form

$$\frac{v_o}{v} - 1 = \frac{B\rho^{\gamma-1}(1 + y)}{c^2} . \tag{23}$$

c^2 may be obtained as a function of ρ and y by eliminating K between (14) and (17), and then using $P = B\rho^\gamma (1 + y)$ to eliminate P; the result is

$$c^2 = B\rho^{\gamma-1} \left(\gamma + \left\{\frac{1 + \alpha}{\alpha}\right\} y\right) . \tag{24}$$

Inserting (24) into (23) we obtain $\frac{v_0}{v}$ as a function of y:

$$\frac{v_0}{v} = 1 + \frac{(1 + y)}{\gamma + \left\{\frac{1 + \alpha}{\alpha}\right\} y} . \tag{25}$$

The next step is to obtain v_0 itself as a function of y; this will enable us to solve for the parameter y as a function of the known quantity v_0.

We write the R-H equation for the energy in the form

$$E = Q + \frac{1}{2} P (v_0 - v) = Q + \frac{1}{2} Pv \left(\frac{v_0}{v} - 1\right) , \tag{26}$$

where Q is the chemical energy released by each gram of explosive; and using (25), this becomes:

$$E = Q + \frac{1}{2} Pv \left(\frac{1 + y}{\gamma + \left\{\frac{1 + \alpha}{\alpha}\right\} y}\right) . \tag{27}$$

Eliminating P by using $P = B\rho^\gamma (1 + y)$ we obtain

$$\frac{E}{Q} = 1 + \frac{B}{Q} \frac{(1 + y)^2}{2v^{\gamma-1}} \left(\frac{1}{\gamma + y \left\{\frac{1 + \alpha}{\alpha}\right\}}\right) . \tag{28}$$

Another expression for E/Q may be obtained from equation (9):

$$\frac{E}{Q} = \frac{B}{Q} \frac{\alpha}{v^{\gamma-1}} \left\{y + \frac{1}{\alpha(\gamma-1)}\right\} . \tag{29}$$

Equating (28) and (29), and solving for v, we obtain

$$v^{\gamma-1} = \frac{B}{Q}\left(\alpha y + \frac{1}{\gamma-1} - \frac{(1+y)^2}{2\left(\gamma + \left\{\frac{1+\alpha}{\alpha}\right\}y\right)}\right) . \tag{30}$$

Eliminating v between (30) and (25), we obtain the expression:

$$v_o = \left(\frac{B}{Q}\right)^{\frac{1}{\gamma-1}}\left\{\alpha y + \frac{1}{\gamma-1} - \frac{(y+1)^2}{2w}\right\}^{\frac{1}{\gamma-1}}\left(1 + \frac{1+y}{w}\right), \tag{31}$$

where

$$w = v + \left\{\frac{1+\alpha}{\alpha}\right\}y . \tag{32}$$

Since v_o, the specific volume of the solid explosive, is a known quantity, we may solve (31) for y, by an iterative process. Since v is a known function of y, by virtue of (30), we can find P by using the expression $P = \frac{B}{v^{\gamma}}(1+y)$; E may be found from (28) or (29); and c^2 may be found from equation (24).

The particle velocity at the front, u, may be found from (20), and is given by

$$u = \frac{c(1+y)}{\gamma + \left\{\frac{1+\alpha}{\alpha}\right\}y} . \tag{33}$$

Finally, the detonation velocity can be found from

$$D = u + c = c\left\{1 + \frac{1+y}{\gamma + \left\{\frac{1+\alpha}{\alpha}\right\}y}\right\} . \tag{34}$$

Thus, the detonation velocity is seen to be a function of v_o, the initial specific volume, corresponding to the well-known experimental result for solid explosives.

EVALUATION OF PARAMETERS

The three undetermined parameters, γ, α, and B/Q, which appear in the LSZK equation of state, must be evaluated by using experimental data. It can be seen from equation (14), which describes the isentropic P-ρ relation for an LSZK substance, that if $\frac{1+\alpha}{\alpha} < \gamma$, P ($\rho$) approaches $K\rho^{\frac{1+\alpha}{\alpha}}$ as ρ approaches zero. We assume that in the limit of low pressures the detonation products behave as ideal gases, with a constant value of the specific heat ratio, denoted here by κ. (A reasonable value for κ seems to be 1.34. obtainable by averaging the gammas for the various gaseous constituents according to the composition of the products at low pressure.) It is thus clear that in order to obtain the correct behavior of the detonation products at low pressures, we must set $\alpha = \frac{1}{\kappa - 1}$.

The remaining constants may be evaluated by referring to the experimental results for the dependence of the detonation velocity on the density. After a particular value is assigned for γ ($\gamma > \kappa$), a series of values for B/Q may be obtained by carrying out a point by point comparison of the theoretical plot of ln D vs. ($\ln \rho_0 + \frac{1}{\gamma - 1} \ln \frac{B}{Q}$) (obtainable from equations (31) and (34)) with the experimental plot of ln D vs. ln ρ_0. Since B/Q must be a constant, the accuracy of the fit is determined by the amount of variation in the values of B/Q obtained, and γ may be adjusted to make this variation a minimum.

This process has been carried out for TNT, using an empirical relation between detonation velocity and loading density determined at the Explosives Research Laboratory, at Bruceton.[8] This relation may be written $D = 0.1785 + 0.3225\ \rho_0$, where D is in centimeters per microsecond and ρ_0 is in grams per cubic centimeter. Using $\kappa = 1.34$, and with the heat of detonation chosen[11] to be 1018 cal/gm, the results are $\gamma = 2.78$, $B/Q = 0.53562$ and $\alpha = 2.9412$.

Equations (31) and (34) may now be utilized to provide the dependence of the detonation velocity on the loading density, by letting the parameter y run through a range of values. Table 1 gives a comparison of this theoretical curve with the empirical relationship, and it can be seen that the fit is quite good.

It is interesting to note that this formalism predicts an upper density limit to the detonability, at the loading density $\rho_0 = 1.793$ gm/cc and detonation velocity $D = 0.757$ cm/usec. This comes about because of the fact that at this point the value of the parameter y is zero (y decreases with increasing loading density), and y cannot be negative, because of its physical meaning as a ratio of pressures (see equation (7)).

In fact, equation (7) implies that at this limiting point, the only contribution to the pressure comes from the elastic part, while the thermal pressure vanishes. Zeldovich and Kompaneets[8] have the following to say about the physical significance of this phenomenon: "It is possible to have charge densities for which the thermal energy is much smaller than the elastic part. This corresponds to y being nearly zero....It is not quite clear what happens when the charge density is large. It can be assumed that in this case the dissociation reaction does not go to completion, since the supply of chemical energy is insufficient for overcoming the work required by the elastic repulsion forces between the molecules. It appears as though the chemical energy does not suffice for the molecular rearrangement which leads to an explosion." This prediction is especially interesting inasmuch as it is known that TNT exhibits increasing resistance to detonation with increasing loading density, as, in fact, do most solid explosives.

Now that values for the constants in the LSZK equation have been arrived at, the conditions at the Chapman-Jouguet state may be computed by using the expressions developed in the preceding section. This has been done for TNT at several loading densities and the results are presented in Table 2. (The temperatures were calculated using $C_v = 0.3$ cal/gm-degree.) Table 3 presents experimental values for the C-J state, determined by Dremin, et al;[12] the correspondence between calculated values and experiment appears good, except for the temperatures, which seem to be far below the generally accepted values for detonation temperatures of several thousand degrees.

The fact that the ratio of elastic pressure to total pressure increases as the loading density increases may be verified in the last column of Table 2. For instance, for $\rho_0 = 1.625$, this ratio is 0.974, which means that, for the isentrope given in equation (14), 97.4% of the pressure comes from the elastic pressure term. For $\rho_0 = 1.00$ gm/cc, this ratio is 0.805.

Consequently, in the vicinity of the Chapman-Jouguet state, the LSZK isentrope may be approximated by a polytropic relation, with exponent equal to 2.78. In this connection, it is interesting to note the experimental results of Deal,[5] which indicate that the explosion products isentrope for RDX-TNT may be fitted quite closely to a polytropic P-ρ relation, with $\gamma = 2.77$, at least down to 500 bars. It thus seems likely that the LSZK equation of state for TNT not only yields the proper D vs ρ_0 relationship, but also provides the proper isentrope, both in the vicinity of the Chapman-Jouguet state and in the large expansion limit of low pressure and density.

FLOW FIELD BEHIND DETONATION SHOCK

The isentropic flow behind a detonation shock in a spherical explosive is governed by the differential equations:*

$$\frac{du}{d\xi} = \frac{2\,uc^2}{\xi\,\{(u-\xi)^2 - c^2\}} \tag{36}$$

$$\frac{dc^2}{d\xi} = \frac{2\,uc^2\,(\xi - u)}{\{(u-\xi)^2 - c^2\}\xi}\,f\ , \tag{37}$$

where
u = particle velocity

r = radial distance of detonation shock from origin

$\xi = \frac{r}{t}$, t = time

c = sound speed

$$f = \left(\frac{\rho}{dP/d\rho}\right)\frac{d^2P}{d\rho^2}\ ,\ \text{where}\ \rho = \text{density} = \frac{1}{v}\ . \tag{38}$$

Calculating f by means of (14), we obtain:

$$f = \frac{\frac{K}{\alpha}\,\frac{(1+\alpha)}{\alpha} + B\gamma\,(\gamma - 1)\rho^{\gamma - 1 - \frac{1}{\alpha}}}{K\left(\frac{1+\alpha}{\alpha}\right) + B\gamma\rho^{\gamma - 1 - \frac{1}{\alpha}}}\ . \tag{39}$$

To utilize (39) in the system of differential equations (36), (37), it is necessary to express f as a function of c^2. This may be done (in principle) by solving (17) for ρ in terms of c^2, and substituting the result into (39). Unfortunately, it is not possible to invert (17) analytically, in closed form, so that an alternative approach must be used. The procedure chosen here is to convert equations (36) and (37) into a set in which the dependent variables are u and ρ, rather than u and c^2. In this case, we can use f in the form (39), as a function of ρ. To effect this change of variable we make use of the equation

$$\frac{dc^2}{d\xi} = \frac{dc^2}{d\rho}\,\frac{d\rho}{d\xi} \tag{40}$$

Since $c^2 = dP/d\rho$ in the isentropic flow, we may put $dc^2/d\rho = d^2P/d\rho^2$ and using (17) we get:

$$\frac{dc^2}{d\rho} = \frac{K}{\alpha}\left(\frac{1+\alpha}{\alpha}\right)\rho^{\frac{1-\alpha}{\alpha}} + B\gamma\,(\gamma - 1)\rho^{\gamma - 2} \qquad (41)$$

Consequently, $\frac{dc^2}{d\xi} = \left\{\frac{K}{\alpha}\left(\frac{1+\alpha}{\alpha}\right)\rho^{\frac{1-\alpha}{\alpha}} + B\gamma\,(\gamma - 1)\rho^{\gamma - 2}\right\}\frac{d\rho}{d\xi}$, and the differential equations become:

$$\frac{du}{d\xi} = \frac{2\,uc^2}{\xi\{(u - \xi)^2 - c^2\}} \qquad (42)$$

$$\frac{d\rho}{d\xi} = \frac{2\,uc^2\,(\xi - u)}{\{(u - \xi)^2 - c^2\}\xi}\;\frac{f(\rho)}{\left\{\frac{K}{\alpha}\left(\frac{1+\alpha}{\alpha}\right)\rho^{\frac{1-\alpha}{\alpha}} + B\gamma\,(\gamma - 1)\rho^{\gamma - 2}\right\}}, \qquad (43)$$

where $c^2 = K\left(\frac{1+\alpha}{\alpha}\right)\rho^{\frac{1}{\alpha}} + B\gamma\rho^{\gamma - 1}$, and $f(\rho)$ is given by (39). These equations are to be solved subject to the conditions $u = u_D$, $\rho = \rho_D$ at $\xi = D$, where

D = detonation velocity

u_D = particle velocity at the detonation shock

ρ_D = density at the detonation shock.

u_D and ρ_D may be found from (33) and (25), after y has been found from equation (31).

These calculations have been carried out for TNT on an IBM-7090 electronic computer, for the loading densities 1.625, 1.59, 1.45, 1.30, 1.14, and 1.00 gm/cc. The results are given in Tables 4-9. The first column is a dimensionless distance, the radius of the original charge being taken as the unit. Pressures are in megabars, velocities in centimeters per microsecond, energy densities in megabar-cc per gram and densities in grams per cubic centimeter. It will be seen that the parameters vary in the well-known way first demonstrated by Taylor,[3] with the region of constant state surrounding the origin.

CONCLUDING REMARKS

Up until now, very little has been said about the temperature. To evaluate this quantity, we must know the value of C_V, which is not determined by the other constants. (Only the ratio C_V/C_{V1} is determined by equation (4).) If C_V is taken to be 0.3 cal/gm, an approximate average value for detonation products, the C-J temperature (for $\rho_0 = 1.625$ gm/cc) turns out to be 582.9°K, which seems to be too low. This is connected with the phenomenon of the decreasing importance of the thermal pressure with increasing loading density, which was mentioned above. Though this phenomenon is consistent with the known resistance to detonation of TNT at high densities, and with the experimental results of Deal,[8] it is not yet certain whether it is a real effect or whether it is a result of the incompleteness of the LSZK theory* In any case, it is believed that in all applications where the temperature is not needed, and only an (E, p, v) equation of state is required (such as the calculation of the non-reactive, isentropic expansion of detonation products by means of hydrodynamic computer codes), the LSZK equation of state (in particular, equation (3)) may be used with confidence.

It is probably not possible to decide on the correctness of the LSZK equation of state by experimental observations of the detonation process alone. A possible approach is to use the results for the distribution behind the detonation as initial conditions for a hydrodynamic code computation of the detonation of a sphere of TNT in air, using the LSZK equation of state for the expanding detonation products. The motion of the second shock through the product gases is expected to be a sensitive function of the equation of state used, and one can attempt to compare the calculated results with the evidence obtained from photographic records. The behavior of the air shock, though a much less sensitive function of the equation of state for explosion products, might also provide a useful check.

Preliminary hydrodynamic calculations have already been carried out on an IBM-7090 and are reported elsewhere;[10] more refined computations are in progress at the present time.

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* Jacobs[13] has pointed out that a reinterpretation of the partition between elastic and thermal energy leads to a theory which does not involve a limiting density, or vanishing thermal pressure. This theory retains the LSZK form for the equation of state, but does not make use of Zeldovich's[9] arguments for the physical meaning of the constants C_{V1}, C_{V2}, and C_V.

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Table 1

Comparison of Detonation Velocities Calculated for
LSZK Substance with Detonation Velocities Determined at Bruceton

$\rho_0 (\frac{gm}{cc})$	$D(\frac{cm}{\mu sec})$; LSZK	$D(\frac{cm}{\mu sec})$; (Bruceton)
1.7935	0.7572	0.7569
1.6620	0.7146	0.7145
1.5535	0.6795	0.6795
1.4412	0.6433	0.6433
1.3655	0.6189	0.6189
1.2995	0.5977	0.5976
1.2412	0.5791	0.5788
1.1773	0.5588	0.5582
1.1320	0.5444	0.5436
1.1009	0.5345	0.5335
1.0034	0.5039	0.5021
0.9590	0.4900	0.4878
0.9256	0.4797	0.4770
0.9010	0.4720	0.4691
0.8565	0.4584	0.4547
0.8082	0.4437	0.4391
0.7703	0.4322	0.4269
0.7331	0.4211	0.4149

Table 2

Detonation Parameters Calculated with
LSZK Equation of State, for TNT, Q = 1018 cal/gm

ρ_0 (gm/cc)	P(Kbars)	E($\frac{\text{megabar-cc}}{\text{gram}}$)	ρ($\frac{\text{gm}}{\text{cc}}$)	u($\frac{\text{cm}}{\text{usec}}$)	D($\frac{\text{cm}}{\text{usec}}$)	T($\frac{\text{degree}}{\text{Kelvin}}$)	$\frac{\text{P(elastic)}}{\text{P(total)}}$
1.625	214.3	0.06022	2.217	0.188	0.703	582.9	0.974
1.59	203.5	0.05973	2.171	0.185	0.691	698.4	0.968
1.45	163.8	0.0579	1.988	0.175	0.646	1141.7	0.941
1.30	127.6	0.05607	1.792	0.164	0.598	1582.5	0.905
1.14	95.4	0.05431	1.583	0.153	0.547	2013.3	0.857
1.00	72.2	0.05293	1.400	0.144	0.503	2356.7	0.805

Table 3

Experimental Values for Detonation Parameters
of TNT (Dremin, et al)

$\rho_0 (\frac{gm}{cc})$	P(kbars)	$u(\frac{cm}{\mu sec})$	$D(\frac{cm}{\mu sec})$
1.59	202	0.183 0.180	0.694
1.45	162	0.172 0.168	0.650
1.30	123	0.158 0.156	0.600
1.14	92	0.145 0.142	0.557
1.00	64	0.130 0.129	0.510

Table 4

Detonation Wave for TNT (ρ_0 = 1.625 gm/cc)

DISTANCE X/RADIUS	VELOCITY CM/USEC	DENSITY GM/CC	PRESSURE MEGABARS	ENERGY DENS (MEG-CC)/GM
0.	0.	1.29163E 00	4.91537E-02	2.63062E-02
4.57265E-02	0.	1.29163E 00	4.91537E-02	2.63062E-02
9.14531E-02	0.	1.29163E 00	4.91537E-02	2.63062E-02
1.37180E-01	0.	1.29163E 00	4.91537E-02	2.63062E-02
1.82906E-01	0.	1.29163E 00	4.91537E-02	2.63062E-02
2.28633E-01	0.	1.29163E 00	4.91537E-02	2.63062E-02
2.74359E-01	0.	1.29163E 00	4.91537E-02	2.63062E-02
3.20086E-01	0.	1.29163E 00	4.91537E-02	2.63062E-02
3.65812E-01	0.	1.29163E 00	4.91537E-02	2.63062E-02
4.11539E-01	0.	1.29163E 00	4.91537E-02	2.63062E-02
4.57265E-01	5.62295E-05	1.29163E 00	4.91537E-02	2.63062E-02
4.85730E-01	2.86409E-03	1.30326E 00	5.03598E-02	2.66499E-02
5.14195E-01	6.72565E-03	1.31989E 00	5.21153E-02	2.71453E-02
5.42659E-01	1.11811E-02	1.33975E 00	5.42632E-02	2.77425E-02
5.71124E-01	1.60719E-02	1.36220E 00	5.67594E-02	2.84252E-02
5.99589E-01	2.13167E-02	1.38690E 00	5.95935E-02	2.91858E-02
6.28053E-01	2.68724E-02	1.41367E 00	6.27591E-02	3.00208E-02
6.56518E-01	3.27201E-02	1.44242E 00	6.62796E-02	3.09299E-02
6.84983E-01	3.88586E-02	1.47311E 00	7.01775E-02	3.19152E-02
7.13447E-01	4.53024E-02	1.50582E 00	7.44899E-02	3.29814E-02
7.41912E-01	5.20822E-02	1.54067E 00	7.92682E-02	3.41357E-02
7.70377E-01	5.92466E-02	1.57788E 00	8.45828E-02	3.53890E-02
7.98841E-01	6.68685E-02	1.61777E 00	9.05303E-02	3.67566E-02
8.27306E-01	7.50551E-02	1.66085E 00	9.72468E-02	3.82610E-02
8.55771E-01	8.39676E-02	1.70785E 00	1.04932E-01	3.99349E-02
8.84235E-01	9.38604E-02	1.75995E 00	1.13896E-01	4.18301E-02
9.00523E-01	1.00118E-01	1.79278E 00	1.19789E-01	4.30454E-02
9.15477E-01	1.06375E-01	1.82544E 00	1.25843E-01	4.42709E-02
9.29105E-01	1.12632E-01	1.85799E 00	1.32053E-01	4.55045E-02
9.41417E-01	1.18890E-01	1.89013E 00	1.38399E-01	4.67442E-02
9.52435E-01	1.25147E-01	1.92200E 00	1.44880E-01	4.79877E-02
9.62185E-01	1.31405E-01	1.95357E 00	1.51482E-01	4.92332E-02
9.70701E-01	1.37662E-01	1.98476E 00	1.58192E-01	5.04786E-02
9.78022E-01	1.43919E-01	2.01555E 00	1.65000E-01	5.17220E-02
9.84193E-01	1.50177E-01	2.04590E 00	1.71892E-01	5.29615E-02
9.89262E-01	1.56434E-01	2.07578E 00	1.78856E-01	5.41953E-02
9.93282E-01	1.62691E-01	2.10517E 00	1.85883E-01	5.54217E-02
9.96309E-01	1.68949E-01	2.13405E 00	1.92952E-01	5.66392E-02
9.98398E-01	1.75206E-01	2.16240E 00	2.00060E-01	5.78461E-02
9.99609E-01	1.81463E-01	2.19020E 00	2.07191E-01	5.90411E-02
1.00000E 00	1.87721E-01	2.21743E 00	2.14333E-01	6.02228E-02

Table 5

Detonation Wave for TNT (ρ_0 = 1.59 gm/cc)

DISTANCE X/RADIUS	VELOCITY CM/USEC	DENSITY GM/CC	PRESSURE MEGABARS	ENERGY DENS (MEG-CC)/GM
0.	0.	1.26271E 00	4.67753E-02	2.67108E-02
4.56064E-02	0.	1.26271E 00	4.67753E-02	2.67108E-02
9.12129E-02	0.	1.26271E 00	4.67753E-02	2.67108E-02
1.36819E-01	0.	1.26271E 00	4.67753E-02	2.67108E-02
1.82426E-01	0.	1.26271E 00	4.67753E-02	2.67108E-02
2.28032E-01	0.	1.26271E 00	4.67753E-02	2.67108E-02
2.73639E-01	0.	1.26271E 00	4.67753E-02	2.67108E-02
3.19245E-01	0.	1.26271E 00	4.67753E-02	2.67108E-02
3.64851E-01	0.	1.26271E 00	4.67753E-02	2.67108E-02
4.10458E-01	0.	1.26271E 00	4.67753E-02	2.67108E-02
4.56064E-01	9.91348E-05	1.26271E 00	4.67753E-02	2.67108E-02
4.84596E-01	2.72887E-03	1.27354E 00	4.78596E-02	2.70294E-02
5.13127E-01	6.52804E-03	1.28980E 00	4.95179E-02	2.75111E-02
5.41659E-01	1.09217E-02	1.30925E 00	5.15509E-02	2.80933E-02
5.70191E-01	1.57492E-02	1.33128E 00	5.39162E-02	2.87595E-02
5.98722E-01	2.09282E-02	1.35553E 00	5.66005E-02	2.95019E-02
6.27254E-01	2.64154E-02	1.38182E 00	5.96061E-02	3.03171E-02
6.55785E-01	3.21914E-02	1.41005E 00	6.29463E-02	3.12047E-02
6.84317E-01	3.82546E-02	1.44021E 00	6.66453E-02	3.21667E-02
7.12848E-01	4.46192E-02	1.47235E 00	7.07384E-02	3.32074E-02
7.41380E-01	5.13151E-02	1.50660E 00	7.52742E-02	3.43340E-02
7.69912E-01	5.83903E-02	1.54317E 00	8.03196E-02	3.55570E-02
7.98443E-01	6.59166E-02	1.58238E 00	8.59663E-02	3.68914E-02
8.26975E-01	7.39999E-02	1.62471E 00	9.23438E-02	3.83587E-02
8.55506E-01	8.27990E-02	1.67091E 00	9.96419E-02	3.99912E-02
8.84038E-01	9.25653E-02	1.72213E 00	1.08155E-01	4.18390E-02
9.00348E-01	9.87363E-02	1.75437E 00	1.13746E-01	4.30226E-02
9.15325E-01	1.04907E-01	1.78645E 00	1.19491E-01	4.42160E-02
9.28974E-01	1.11078E-01	1.81832E 00	1.25382E-01	4.54171E-02
9.41307E-01	1.17249E-01	1.84995E 00	1.31408E-01	4.66241E-02
9.52344E-01	1.23420E-01	1.88129E 00	1.37559E-01	4.78347E-02
9.62112E-01	1.29591E-01	1.91230E 00	1.43825E-01	4.90471E-02
9.70643E-01	1.35762E-01	1.94294E 00	1.50195E-01	5.02593E-02
9.77978E-01	1.41933E-01	1.97319E 00	1.56656E-01	5.14694E-02
9.84161E-01	1.48104E-01	2.00300E 00	1.63199E-01	5.26756E-02
9.89240E-01	1.54275E-01	2.03236E 00	1.69810E-01	5.38762E-02
9.93269E-01	1.60446E-01	2.06124E 00	1.76479E-01	5.50696E-02
9.96301E-01	1.66617E-01	2.08961E 00	1.83193E-01	5.62540E-02
9.98395E-01	1.72789E-01	2.11746E 00	1.89941E-01	5.74282E-02
9.99609E-01	1.78960E-01	2.14477E 00	1.96712E-01	5.85906E-02
1.00000E 00	1.85131E-01	2.17153E 00	2.03493E-01	5.97400E-02

Table 6

Detonation Wave for TNT (ρ_0 = 1.45 gm/cc)

DISTANCE X/RADIUS	VELOCITY CM/USEC	DENSITY GM/CC	PRESSURE MEGABARS	ENERGY DENS (MEG-CC)/GM
0.	0.	1.14661E 00	3.80136E-02	2.82422E-02
4.53543E-02	0.	1.14661E 00	3.80136E-02	2.82422E-02
9.07087E-02	0.	1.14661E 00	3.80136E-02	2.82422E-02
1.36063E-01	0.	1.14661E 00	3.80136E-02	2.82422E-02
1.81417E-01	0.	1.14661E 00	3.80136E-02	2.82422E-02
2.26772E-01	0.	1.14661E 00	3.80136E-02	2.82422E-02
2.72126E-01	0.	1.14661E 00	3.80136E-02	2.82422E-02
3.17480E-01	0.	1.14661E 00	3.80136E-02	2.82422E-02
3.62835E-01	0.	1.14661E 00	3.80136E-02	2.82422E-02
4.08189E-01	0.	1.14661E 00	3.80136E-02	2.82422E-02
4.53543E-01	1.71616E-04	1.14661E 00	3.80136E-02	2.82422E-02
4.82184E-01	2.46944E-03	1.15583E 00	3.88149E-02	2.85394E-02
5.10825E-01	6.05588E-03	1.17077E 00	4.01368E-02	2.89452E-02
5.39465E-01	1.02157E-02	1.18871E 00	4.17629E-02	2.94732E-02
5.68106E-01	1.47906E-02	1.20966E 00	4.36576E-02	3.00777E-02
5.96747E-01	1.97000E-02	1.23149E 00	4.58094E-02	3.07513E-02
6.25387E-01	2.49011E-02	1.25561E 00	4.82196E-02	3.14905E-02
6.54028E-01	3.03746E-02	1.28194E 00	5.08989E-02	3.22947E-02
6.82669E-01	3.61180E-02	1.30986E 00	5.38663E-02	3.31653E-02
7.11309E-01	4.21442E-02	1.33962E 00	5.71498E-02	3.41063E-02
7.39950E-01	4.84808E-02	1.37133E 00	6.07893E-02	3.51237E-02
7.68590E-01	5.51725E-02	1.40519E 00	6.48353E-02	3.62268E-02
7.97231E-01	6.22864E-02	1.44149E 00	6.93640E-02	3.74287E-02
8.25872E-01	6.99216E-02	1.48069E 00	7.44777E-02	3.87486E-02
8.54512E-01	7.82267E-02	1.52345E 00	8.03280E-02	4.02149E-02
8.83153E-01	8.74366E-02	1.57083E 00	8.71497E-02	4.18718E-02
8.99565E-01	9.32657E-02	1.60073E 00	9.16390E-02	4.29342E-02
9.14641E-01	9.90948E-02	1.63048E 00	9.62536E-02	4.40050E-02
9.28386E-01	1.04924E-01	1.66006E 00	1.00986E-01	4.50622E-02
9.40811E-01	1.10753E-01	1.68941E 00	1.05830E-01	4.61642E-02
9.51934E-01	1.16582E-01	1.71850E 00	1.10775E-01	4.72491E-02
9.61780E-01	1.22411E-01	1.74728E 00	1.15814E-01	4.83350E-02
9.70383E-01	1.28240E-01	1.77574E 00	1.20937E-01	4.94204E-02
9.77781E-01	1.34069E-01	1.80383E 00	1.26136E-01	5.05034E-02
9.84018E-01	1.39899E-01	1.83152E 00	1.31400E-01	5.15825E-02
9.89142E-01	1.45728E-01	1.85879E 00	1.36721E-01	5.26562E-02
9.93207E-01	1.51557E-01	1.88561E 00	1.42089E-01	5.37229E-02
9.96267E-01	1.57386E-01	1.91197E 00	1.47494E-01	5.47813E-02
9.98380E-01	1.63215E-01	1.93784E 00	1.52926E-01	5.58300E-02
9.99605E-01	1.69044E-01	1.96321E 00	1.58377E-01	5.68679E-02
1.00000E 00	1.74873E-01	1.98806E 00	1.63836E-01	5.78936E-02

Table 7

Detonation Wave for TNT (ρ_0 = 1.30 gm/cc)

DISTANCE X/RADIUS	VELOCITY CM/USEC	DENSITY GM/CC	PRESSURE MEGABARS	ENERGY DENS (MEG-CC)/GM
0.	0.	1.02138E 00	2.99005E-02	2.97234E-02
4.53858E-02	0.	1.02138E 00	2.99005E-02	2.97234E-02
9.07715E-02	0.	1.02138E 00	2.99005E-02	2.97234E-02
1.36157E-01	0.	1.02138E 00	2.99005E-02	2.97234E-02
1.81543E-01	0.	1.02138E 00	2.99005E-02	2.97234E-02
2.26929E-01	0.	1.02138E 00	2.99005E-02	2.97234E-02
2.72315E-01	0.	1.02138E 00	2.99005E-02	2.97234E-02
3.17700E-01	0.	1.02138E 00	2.99005E-02	2.97234E-02
3.63086E-01	0.	1.02138E 00	2.99005E-02	2.97234E-02
4.08472E-01	0.	1.02138E 00	2.99005E-02	2.97234E-02
4.53858E-01	4.92819E-05	1.02138E 00	2.99005E-02	2.97234E-02
4.82401E-01	2.52551E-03	1.03098E 00	3.06106E-02	2.99994E-02
5.10944E-01	5.93218E-03	1.04474E 00	3.16466E-02	3.03970E-02
5.39487E-01	9.86073E-03	1.06118E 00	3.29137E-02	3.08755E-02
5.68030E-01	1.41695E-02	1.07977E 00	3.43860E-02	3.14212E-02
5.96573E-01	1.87854E-02	1.10022E 00	3.60553E-02	3.20276E-02
6.25116E-01	2.36693E-02	1.12239E 00	3.79229E-02	3.26914E-02
6.53659E-01	2.88034E-02	1.14619E 00	3.99970E-02	3.34120E-02
6.82202E-01	3.41857E-02	1.17161E 00	4.22921E-02	3.41905E-02
7.10745E-01	3.98276E-02	1.19870E 00	4.48297E-02	3.50302E-02
7.39288E-01	4.57546E-02	1.22754E 00	4.76396E-02	3.59362E-02
7.67831E-01	5.20076E-02	1.25833E 00	5.07624E-02	3.69165E-02
7.96374E-01	5.86481E-02	1.29133E 00	5.42537E-02	3.79822E-02
8.24917E-01	6.57666E-02	1.32694E 00	5.81922E-02	3.91499E-02
8.53460E-01	7.34985E-02	1.36576E 00	6.26922E-02	4.04437E-02
8.82003E-01	8.20569E-02	1.40873E 00	6.79310E-02	4.19014E-02
8.98544E-01	8.75274E-02	1.43613E 00	7.14140E-02	4.28445E-02
9.13748E-01	9.29978E-02	1.46341E 00	7.49958E-02	4.37944E-02
9.27617E-01	9.84683E-02	1.49053E 00	7.86728E-02	4.47496E-02
9.40161E-01	1.03939E-01	1.51746E 00	8.24330E-02	4.57084E-02
9.51395E-01	1.09409E-01	1.54416E 00	8.62759E-02	4.66693E-02
9.61344E-01	1.14880E-01	1.57059E 00	9.01929E-02	4.76306E-02
9.70040E-01	1.20350E-01	1.59672E 00	9.41760E-02	4.85909E-02
9.77520E-01	1.25821E-01	1.62251E 00	9.82206E-02	4.95486E-02
9.83828E-01	1.31291E-01	1.64795E 00	1.02317E-01	5.05024E-02
9.89012E-01	1.36762E-01	1.67301E 00	1.06457E-01	5.14508E-02
9.93125E-01	1.42232E-01	1.69765E 00	1.10635E-01	5.23926E-02
9.96222E-01	1.47702E-01	1.72187E 00	1.14842E-01	5.33266E-02
9.98361E-01	1.53173E-01	1.74565E 00	1.19072E-01	5.42515E-02
9.99600E-01	1.58643E-01	1.76896E 00	1.23316E-01	5.51663E-02
1.00000E 00	1.64114E-01	1.79180E 00	1.27567E-01	5.60700E-02

Table 8

Detonation Wave for TNT (ρ_0 = 1.14 gm/cc)

DISTANCE X/RADIUS	VELOCITY CM/USEC	DENSITY GM/CC	PRESSURE MEGABARS	ENERGY DENS (MEG-CC)/GM
0.	0.	8.88453E-01	2.26994E-02	3.11573E-02
4.52631E-02	0.	8.88453E-01	2.26994E-02	3.11573E-02
9.05262E-02	0.	8.88453E-01	2.26994E-02	3.11573E-02
1.35789E-01	0.	8.88453E-01	2.26994E-02	3.11573E-02
1.81052E-01	0.	8.88453E-01	2.26994E-02	3.11573E-02
2.26316E-01	0.	8.88453E-01	2.26994E-02	3.11573E-02
2.71579E-01	0.	8.88453E-01	2.26994E-02	3.11573E-02
3.16842E-01	0.	8.88453E-01	2.26994E-02	3.11573E-02
3.62105E-01	0.	8.88453E-01	2.26994E-02	3.11573E-02
4.07368E-01	0.	8.88453E-01	2.26994E-02	3.11573E-02
4.52631E-01	8.34041E-05	8.88453E-01	2.26994E-02	3.11573E-02
4.95417E-01	3.96314E-03	9.03023E-01	2.35974E-02	3.15776E-02
5.38202E-01	9.32355E-03	9.24314E-01	2.49510E-02	3.21966E-02
5.80988E-01	1.54886E-02	9.49978E-01	2.66488E-02	3.29503E-02
6.23774E-01	2.22482E-02	9.79245E-01	2.86750E-02	3.38200E-02
6.66560E-01	2.95268E-02	1.01182E 00	3.10453E-02	3.48008E-02
7.09345E-01	3.73264E-02	1.04769E 00	3.38003E-02	3.58970E-02
7.52131E-01	4.57134E-02	1.08713E 00	3.70077E-02	3.71218E-02
7.94917E-01	5.48296E-02	1.13074E 00	4.07783E-02	3.84999E-02
8.37703E-01	6.49320E-02	1.17961E 00	4.52926E-02	4.00747E-02
8.80488E-01	7.64985E-02	1.23582E 00	5.08731E-02	4.19256E-02
8.93143E-01	8.03235E-02	1.25438E 00	5.28096E-02	4.25463E-02
9.05047E-01	8.41484E-02	1.27290E 00	5.47890E-02	4.31702E-02
9.16197E-01	8.79733E-02	1.29136E 00	5.68095E-02	4.37967E-02
9.26595E-01	9.17982E-02	1.30975E 00	5.88694E-02	4.44253E-02
9.36243E-01	9.56232E-02	1.32804E 00	6.09666E-02	4.50553E-02
9.45147E-01	9.94481E-02	1.34622E 00	6.30992E-02	4.56862E-02
9.53316E-01	1.03273E-01	1.36429E 00	6.52651E-02	4.63173E-02
9.60760E-01	1.07098E-01	1.38222E 00	6.74621E-02	4.69482E-02
9.67491E-01	1.10923E-01	1.40000E 00	6.96879E-02	4.75782E-02
9.73526E-01	1.14748E-01	1.41761E 00	7.19402E-02	4.82068E-02
9.78880E-01	1.18573E-01	1.43506E 00	7.42167E-02	4.88334E-02
9.83573E-01	1.22398E-01	1.45233E 00	7.65149E-02	4.94577E-02
9.87625E-01	1.26223E-01	1.46940E 00	7.88324E-02	5.00789E-02
9.91058E-01	1.30047E-01	1.48627E 00	8.11668E-02	5.06968E-02
9.93896E-01	1.33872E-01	1.50292E 00	8.35156E-02	5.13107E-02
9.96161E-01	1.37697E-01	1.51936E 00	8.58764E-02	5.19203E-02
9.97879E-01	1.41522E-01	1.53557E 00	8.82467E-02	5.25252E-02
9.99074E-01	1.45347E-01	1.55155E 00	9.06240E-02	5.31249E-02
9.99773E-01	1.49172E-01	1.56729E 00	9.30061E-02	5.37191E-02
1.00000E 00	1.52997E-01	1.58278E 00	9.53905E-02	5.43073E-02

Table 9

Detonation Wave for TNT (ρ_0 = 1.00 gm/cc)

DISTANCE X/RADIUS	VELOCITY CM/USEC	DENSITY GM/CC	PRESSURE MEGABARS	ENERGY DENS (MEG-CC)/GM
0.	0.	7.72358E-01	1.74758E-02	3.22656E-02
4.46409E-02	0.	7.72358E-01	1.74758E-02	3.22656E-02
8.92817E-02	0.	7.72358E-01	1.74758E-02	3.22656E-02
1.33923E-01	0.	7.72358E-01	1.74758E-02	3.22656E-02
1.78563E-01	0.	7.72358E-01	1.74758E-02	3.22656E-02
2.23204E-01	0.	7.72358E-01	1.74758E-02	3.22656E-02
2.67845E-01	0.	7.72358E-01	1.74758E-02	3.22656E-02
3.12486E-01	0.	7.72358E-01	1.74758E-02	3.22656E-02
3.57127E-01	0.	7.72358E-01	1.74758E-02	3.22656E-02
4.01768E-01	0.	7.72358E-01	1.74758E-02	3.22656E-02
4.49272E-01	1.28891E-04	7.723[illegible]8E-01	1.74758E-02	3.22656E-02
4.77912E-01	2.15273E-03	7.79461E-01	1.78420E-02	3.24745E-02
5.06551E-01	5.16212E-03	7.90505E-01	1.84196E-02	3.27988E-02
5.35190E-01	8.63988E-03	8.03724E-01	1.91259E-02	3.31893E-02
5.63830E-01	1.24547E-02	8.18707E-01	1.99486E-02	3.36341E-02
5.92469E-01	1.65385E-02	8.35218E-01	2.08816E-02	3.41269E-02
6.21109E-01	2.08542E-02	8.53127E-01	2.19252E-02	3.46647E-02
6.49748E-01	2.53841E-02	8.72368E-01	2.30838E-02	3.52463E-02
6.78387E-01	3.01246E-02	8.92925E-01	2.43650E-02	3.58722E-02
7.07027E-01	3.50840E-02	9.14832E-01	2.578[illegible]4E-02	3.65443E-02
7.35666E-01	4.02828E-02	9.38170E-01	2.73462E-02	3.72663E-02
7.64305E-01	4.57547E-02	9.63075E-01	2.90844E-02	3.80437E-02
7.92945E-01	5.15505E-02	9.8976[illegible]E-01	3.10251E-02	3.88846E-02
8.21584E-01	5.77454E-02	1.01854E 00	3.32107E-02	3.98009E-02
8.50223E-01	6.44517E-02	1.04984E 00	3.57028E-02	4.08101E-02
8.78863E-01	7.13447E-02	1.08452E 00	3.85960E-02	4.19395E-02
8.95739E-01	7.66343E-02	1.10694E 00	4.05481E-02	4.26784E-02
9.11281E-01	8.14240E-02	1.12931E 00	4.25581E-02	4.34216E-02
9.25483E-01	8.62136E-02	1.15157E 00	4.46229E-02	4.41678E-02
9.38347E-01	9.10[illegible]32E-02	1.17371E 00	4.67391E-02	4.49156E-02
9.49885E-01	9.57929E-02	1.19567E 00	4.89031E-02	4.56640E-02
9.60118E-01	1.00583E-01	1.21744E 00	5.11110E-02	4.64116E-02
9.69072E-01	1.05372E-01	1.23898E 00	5.33587E-02	4.71573E-02
9.76782E-01	1.10162E-01	1.26026E 00	5.56419E-02	4.78999E-02
9.83290E-01	1.14951E-01	1.28126E 00	5.79564E-02	4.86384E-02
9.88643E-01	1.19741E-01	1.30195E 00	6.02977E-02	4.93716E-02
9.92892E-01	1.24531E-01	1.32231E 00	6.26612E-02	5.00986E-02
9.96093E-01	1.29320E-01	1.34233E 00	6.50424E-02	5.08185E-02
9.98304E-01	1.34110E-01	1.36198E 00	6.74369E-02	5.15303E-02
9.99586E-01	1.39900E-01	1.38125E 00	6.98401E-02	5.22333E-02
1.00000E 00	1.43689E-01	1.40012E 00	7.22476E-02	5.29266E-02

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13 ABSTRACT

Calculations have been made of the flow field in the isentropic region behind a detonation wave in TNT, using the Landau-Stanyukovich equation of state for the detonation products (as described by Zeldovich and Kompaneets). Adjustable constants in this equation have been evaluated by imposing ideal gas behavior on the detonation products in the large expansion (low density) limit, and by fitting to an experimental curve of detonation velocity versus loading density. Calculated values of Chapman-Jouguet variables correspond fairly well with experimental values at various loading densities, with the exception of the temperatures, which seem to be far too low. This is connected with the fact that the theory predicts an upper limit to the loading density at which an explosive will detonate; at this point the thermal energy vanishes and only the elastic energy contributes to the energy of detonation.

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Naval Ordnance Laboratory, White Oak, Md.
(NOL technical report 64-40)
THE FLOW FIELD BEHIND A SPHERICAL DETONATION IN TNT USING THE LANDAU-STANYUKOVICH EQUATION OF STATE FOR DETONATION PRODUCTS, by M. Lutzky. 10 Dec. 1964. 15p. tables. NOL task 248.

UNCLASSIFIED

Calculations have been made of the flow field in the isentropic region behind a detonation wave in TNT. Adjustable constants in this equation have been evaluated by imposing ideal gas behavior on the detonation products in the large expansion limit, and by fitting to an experimental curve of detonation velocity versus loading density.

1. Explosives - Detonation
2. Explosions - Shock waves
I. Title
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III. Project

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